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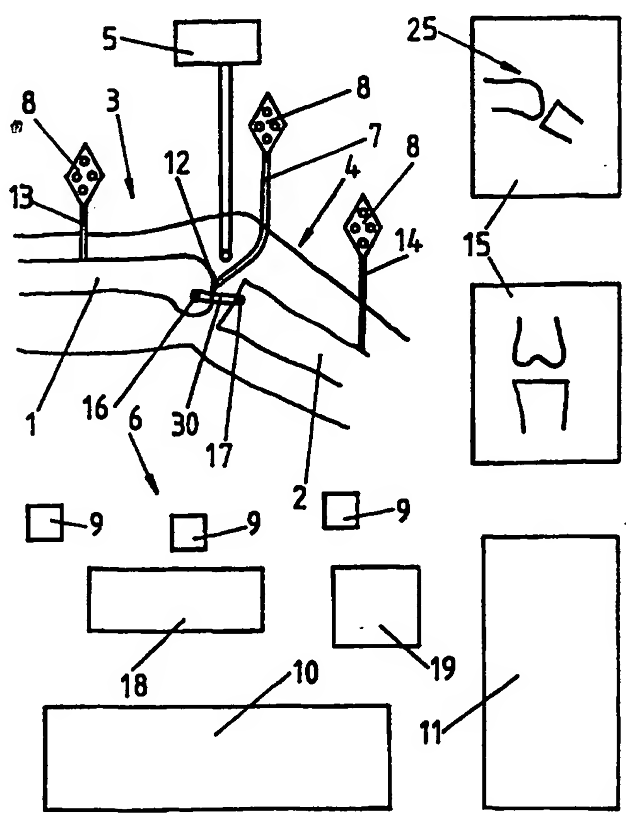
(54) Title: VIRTUAL REPRESENTATION OF A BONE OR A BONE JOINT

(57) Abstract

Device and method for planning a surgical operation by using virtual representation of a bone or a bone joint comprising reference bodies (13; 14) and pointers (7) having references (8) attached, a three-dimensional localizer device (6) comprising sensors (9) or transmitters, a digitizing device (18) and an image processing unit (10). By means of the references (8) and the three-dimensional localizer device (6) the position and the orientation of the reference bodies (13; 14) and the pointers (7) or the pointer tip (12) can be determined and represented at the display (19) of a computer (11). The image processing unit (10) permits the generation of a virtual three-dimensional surface at the display (19) containing the points that were previously determined by means of the pointers (7), the display of any desired and previously acquired relevant element (25) or combination of these elements from any desired angle of observation and the display of stationary or moving elements (25).



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Virtual representation of a bone or a bone joint

The invention relates to a device to virtually represent a bone or a bone joint according to the preamble of claim 1 and to a method for planning a surgical operation by using virtual representation of a bone or a bone joint according to the preamble of claim 15.

A method for computer-assisted knee anterior cruciate ligament reconstruction is known from DESSENNE et al, Computer-Assisted Knee Anterior Cruciate Ligament Reconstruction: First Clinical Tests, Journal of Image Guided Surgery 1:59-64 (1995). The chosen procedure is the patellar tendon bone autograft, whereby the method allows positioning the central part of the ligament graft at the least anisometric sites. A perfect isometry implies that there is no change in the distance between the ligament attachment points at the femur and at the tibia. An anisometry is said to exist when there is a change in the distance during knee flexion and extension. With weak anisometry, the graft is subjected to nearly constant tensile forces. Therefore, the risk of rupture because of excessive tensile force in extension or flexion is reduced and the knee stability is improved. The system involved uses a workstation and a three-dimensional optical localizer to create images that represent knee kinematics. This surgical procedure can be performed in a

classical open surgery or under use of an arthroscope. The success of the reconstruction depends on both the selection of the intraarticular graft position and the initial graft tension. If the insertion sites, initial tension, geometry and mechanical properties of the normal Anterior Cruciate Ligament can be restored during reconstructive surgery, the long-term complications of an Anterior Cruciate Ligament injury can be greatly reduced. To determine the optimal placement of an anterior cruciate ligament graft, the concept of "isometry" has been advocated by many authors. In the described version of the system, the surgeon drills the tibia tunnel without using the computer system. The system is used to optimize the placement of the femoral tunnel only. The method is divided into four steps:

1) A passive flexion-extension is applied to the knee by the surgeon and for about 20-50 knee positions ranging from maximal extension to maximal flexion. At each position the location of two coordinate systems represented by optical bodies that are fixed to the femur and the tibia are computed and stored.

2) A third optical pointer is used by the surgeon to interactively collect surface points arthroscopically. Once the tibia tunnel has been developed, the center of its intraarticular extremity is digitized with the pointer. Then the surgeon acquires surface points on the femoral notch. In an area that corresponds to all possible candidate points for the femoral attachment site a set of 20-100 points is digitized.

3) Anisometry maps are then computed. The result is an "anisometry map" on the femoral surface that can be presented to the surgeon as a pseudocolor image.

4) This step concludes the interactive placement of the femoral tunnel. The surgeon can now locate the least anisometric point on the femoral surface using any standard surgical tool equipped with optical bodies i.e. a drill.

The present invention intends to offer much more information needed to plan an anterior cruciate ligament reconstruction particularly it permits to display a surface section of the femur or of the tibia, the ligament and the planned drill holes. The extension of the ligament in case of knee flexion and extension may be digitized for any femoral or tibial attachment points and the drill holes may be planned such that they may be used as a drill guidance during the surgical operation.

The present invention solves the posed task by means of a device which comprises the features of claim 1 and by means of a method comprising the features of claim 15.

A preferred embodiment of the device according to the present invention comprises reference bodies with at least three electromagnetic or acoustic waves emitting means attached, pointers having at least three electromagnetic or acoustic waves emitting means attached, a three-dimensional localizer device comprising at least two sensors or transmitters and a

digitizing device used to determine the 3-dimensional coordinates of the electromagnetic or acoustic means by what means the position and the orientation of the reference bodies and the pointers or the pointer tips can be digitized by means of the three-dimensional localizer device and represented at the display of a computer and an image processing unit. The image processing unit generates a virtual three-dimensional surface at the display containing the points that were previously digitized by means of the pointers. The digitizing bases on the computation and analysis of electromagnetic wave interference patterns detected by at least three sensors that can be three linear charge-coupled device (CCD) cameras. Another possibility to compute the location of the reference bodies and the points bases on the videogrammetric analysis of the images received by at least two cameras that detect the electromagnetic waves emitted by said means. The image processing unit enables the generation of relevant elements such as a section of the femur or the tibia, the ligament or the femoral or tibial tunnels at or between determined points on the display. Furthermore, the image processing unit permits to display any desired and previously acquired relevant element or combination of these elements from any desired angle of observation, to display stationary or moving relevant elements and allows the representation of the ligament at the display during knee flexion and extension while the resulting extension is digitized.

Also possible is the representation of a dynamic view by using the image processing unit and an arthroscope.

A preferred method according to the invention comprises the performance of the following steps:

a) attachment of reference bodies with electromagnetic or acoustic waves emitting means to the femur and to the tibia whereby the means attached to the reference bodies enable a computation of reference coordinate systems by digitizing that bases on the computation and analysis of electromagnetic wave interference patterns detected by at least three sensors that can be three linear charge-coupled device (CCD) cameras. Another possibility to compute the location of the reference bodies and the pointes bases on the videogrammetric analysis of the images received by at least two cameras that detect the electromagnetic waves emitted by said means;
b) a pointer is used to digitize points which are generated by placing the pointer tip at a desired position of the bones or of the bone joint and press a switch to localize the electromagnetic or acoustic waves emitting means attached at the pointer therewith digitizing the position and orientation of the pointer tip and said points are shown at the display of the computer related to a chosen reference system;
c) by means of an image processing unit a virtual three-dimensional surface at the display is generated containing the points that were previously determined by means of the pointers;

d) a three-dimensional representation of the ligament is generated by means of points that were previously determined by means of the pointers;

e) a three-dimensional simulation of the ligament during flexion-extension of the knee is shown at the display and the optimal locations of the ligament attachment points and of the drill holes are planned by the surgeon;

f) by means of the desirable angle of observation a medio-lateral view or a anterior-posterior view may be chosen; and

g) the different angle of observation enables the surgeon to plan the surgical operation also in view of a ligament impingement simulation.

Further advantageous embodiments of the invention are characterized in the dependent claims.

The invention and implementations of the invention will be disclosed more detailed in connection with the accompanying drawings in which:

Fig. 1 shows the application of the device according to the invention in case of an anterior cruciate ligament reconstruction.

The device according to one implementation of the present invention is illustrated in Fig. 1. Device and method are applied for anterior cruciate ligament reconstruction. At the

femur 1 and at the tibia 2 optical reference bodies 13;14 with Light Emitting Diodes as means 8 are attached each producing a reference system for use with the optical three-dimensional localizer device 6. This three-dimensional localizer device 6 comprises three linear charge-coupled device (CCD) cameras as sensors 9 and a digitizing device 18 used to determine the three-dimensional coordinates of the references 8. Since there are at least three LED's as means 8 attached at the reference bodies 13;14 and at the pointer 7 the position and the orientation of the reference bodies 13;14 and the pointers 7 or the pointer tip 12 can be determined by means of the three-dimensional localizer device (6) and three-dimensionally represented at the display 19 of the computer 11. An image processing unit (10) which is also comprised in the device according to the invention enables the generation of a virtual three-dimensional surface at the display 19 containing the points that were previously determined by means of the pointer 7. By using a pointer 7, an arthroscope 5 and the image processing unit 10 the surgeon determines relevant elements 25 (e.g. a section of the femur 1, a section of the tibia 2, the ligament, a drill hole etc.) at or between certain points on the display 19. By use of the image processing unit 10 any desired and previously acquired relevant element 25 or combination of these elements may be shown at any desired angle of observation at the display 19. For example a medio-lateral view or a anterior-posterior view may be chosen. Furthermore, the image processing unit 10 allows the display of stationary or moving relevant elements 25 and enables a dynamic view by using an

arthroscope 5. Moreover, the image processing unit enables the representation of the ligament at the display 19 during knee flexion and extension and the resulting extension of the ligament is digitized. The shifting to an anterior-posterior view also enables the surgeon to observe the ligament during knee flexion and extension and to perform a ligament impingement simulation. The tunnels 16;17 for the attachments of the ligament (30) as well as the ligament (30) are then determined at the display 19. By means of the drill holes at the display 19 the drill which must then also be provided with references 8 may be guided during the surgical operation.

Claims

1. Device for planning a surgical operation by using virtual representation of a bone or a bone joint comprising

A) a computer;

B) reference bodies (13;14) with at least three electromagnetic or acoustic waves emitting means (8) attached;

C) moveable pointers (7) having at least three electromagnetic or acoustic waves emitting means (8) attached for digitizing points which are generated by placing the pointer tip (12) at a desired location of the bones or of the bone joint and localize the electromagnetic or acoustic waves emitting means (8) attached at the pointer (7) therewith digitizing the position and orientation of the pointer tip (12) and said points being shown at the display (15);

D) a three-dimensional localizer device (6) comprising at least two sensors or transmitters (9) and a digitizing device (18) used to determine the 3-dimensional coordinates of said electromagnetic or acoustic waves emitting means (8) by what means the position and the orientation of the reference bodies (13;14) and of the pointers (7) or the pointer tips (12) can be determined and represented on the display (19) of a computer (11); and

E) an image processing unit (10);

characterized in that

F) the image processing unit (10) generates a virtual three-dimensional surface on the display (19), said surface containing the points that were previously determined by means of the pointers (7); and

G) the image processing unit (10) generates relevant elements (25) at or between determined points on the display (19).

2. Device according to claim 1, characterized in that the image processing unit (10) enables to display any desired and previously acquired relevant element (25) or combination of these elements (25) from different viewing angles.

3. Device according to claim 1 or 2, characterized in that the image processing unit (10) enables to display stationary or moving relevant elements (25).

4. Device according to one of the claims 1 to 3, characterized in that the image processing unit (10) shows a three-dimensional representation of the connection between ligament attachment points (16;17) previously determined via the pointer (7) and represents therewith a ligament (30) on the display (19) during knee flexion and extension.

5. Device according to one of the claims 1 to 4, characterized in that by means of an arthroscope (5) the image processing unit (10) generates an image at the display (19) representing the objects observed by means of the arthroscope (5).

6. Device according to one of the claims 1 to 5, characterised in that said three-dimensional localizer device (6) localizes the position and orientation of said pointers (7) and said reference bodies (13;14) by means of electromagnetic induction.

7. Device according to one of the claims 1 to 6, characterised in that said at least three electromagnetic or acoustic waves emitting means (8) are optical light sources.

8. Device according to one of the claims 1 to 6, characterised in that said at least three electromagnetic or acoustic waves emitting means (8) are light emitting diodes (LED).

9. Device according to one of the claims 1 to 6, characterised in that said at least three electromagnetic or acoustic waves emitting means (8) are infrared light emitting diodes (IRED).

10. Device according to one of the claims 1 to 6, characterised in that said at least three electromagnetic or acoustic waves emitting means (8) are optical reflectors.

11. Device according to one of the claims 1 to 6, characterised in that said at least three electromagnetic or acoustic waves emitting means (8) are acoustical transmitters.

12. Device according to one of the claims 1 to 6, characterised in that said at least three electromagnetic or acoustic waves emitting means (8) are microphones.

13. Device according to one of the claims 1 to 12, characterized in that said relevant elements (25) comprise the ligament, drill holes and previously digitized surfaces of the femur respectively the tibia.

14. Device according to claim 1, characterized in that the position and orientation of the pointer (7) in relation to the reference bodies (13;14) is determined by means of mechanic link devices.

15. Method for planning a surgical operation by using virtual representation of a bone or a bone joint by performing the following steps

A) attachment of reference bodies (13;14) with electromagnetic or acoustic waves emitting means (8) to the femur (1) and to the tibia (2) whereby the at least three means (8) attached to the reference bodies (13;14) enable a computation of reference coordinate systems by means of the three-dimensional localizer device (6);

B) a pointer (7) is used to digitize points which are generated by placing the pointer tip (12) at a desired position of the bones or of the bone joint and press a switch to localize the electromagnetic or acoustic waves emitting means (8) attached at the pointer (7) therewith digitizing the position and orientation of the pointer tip (12) and said points are shown at the display (15) of the computer related to a chosen reference system; and

C) an image processing unit (10) is used,

characterized in that

by means of the image processing unit (10):

D) a virtual three-dimensional surface is generated at the display (19) containing the points that were previously determined by means of the pointers (7); and

E) relevant elements (25) are generated at or between determined points on the display (19).

16. Method according to claim 15, characterized in that any desired and previously acquired relevant element (25) or combination of these elements (25) is displayable at any desired angle of observation and at any scale.

17. Method according to one of the claims 15 or 16, characterized in that a three-dimensional representation of the connection between the ligament attachment points (16;17) previously determined via the pointer (7) is generated representing the ligament (30).

18. Method according to one of the claims 15 to 17, characterized in that a three-dimensional simulation of the ligament during flexion-extension of the knee is shown at the display and the optimal locations of the ligament attachment points (16;17) and of the drill holes are planned by the surgeon.

19. Method according to one of the claims 15 to 18, characterized in that by means of the desirable angle of observation a medio-lateral view or an anterior-posterior view is chosen.

20. Method according to claim 19, characterized in that through the different angle of observation the surgeon plans the surgical operation also in view of a ligament impingement simulation.

21. Method according to one of the claims 15 to 20, characterized in that an arthroscope (5) is used to generate by means of the image processing unit (10) an image at the display (19) representing to objects observed by means of the arthroscope (5).

22. Method according to one of the claims 15 to 21, characterized in that said relevant elements (25) comprise the ligament (30), drill holes generated by putting the pointer (7) at two points and computing a cylinder having an axis through these two points, and previously digitized surfaces of the femur respectively the tibia.

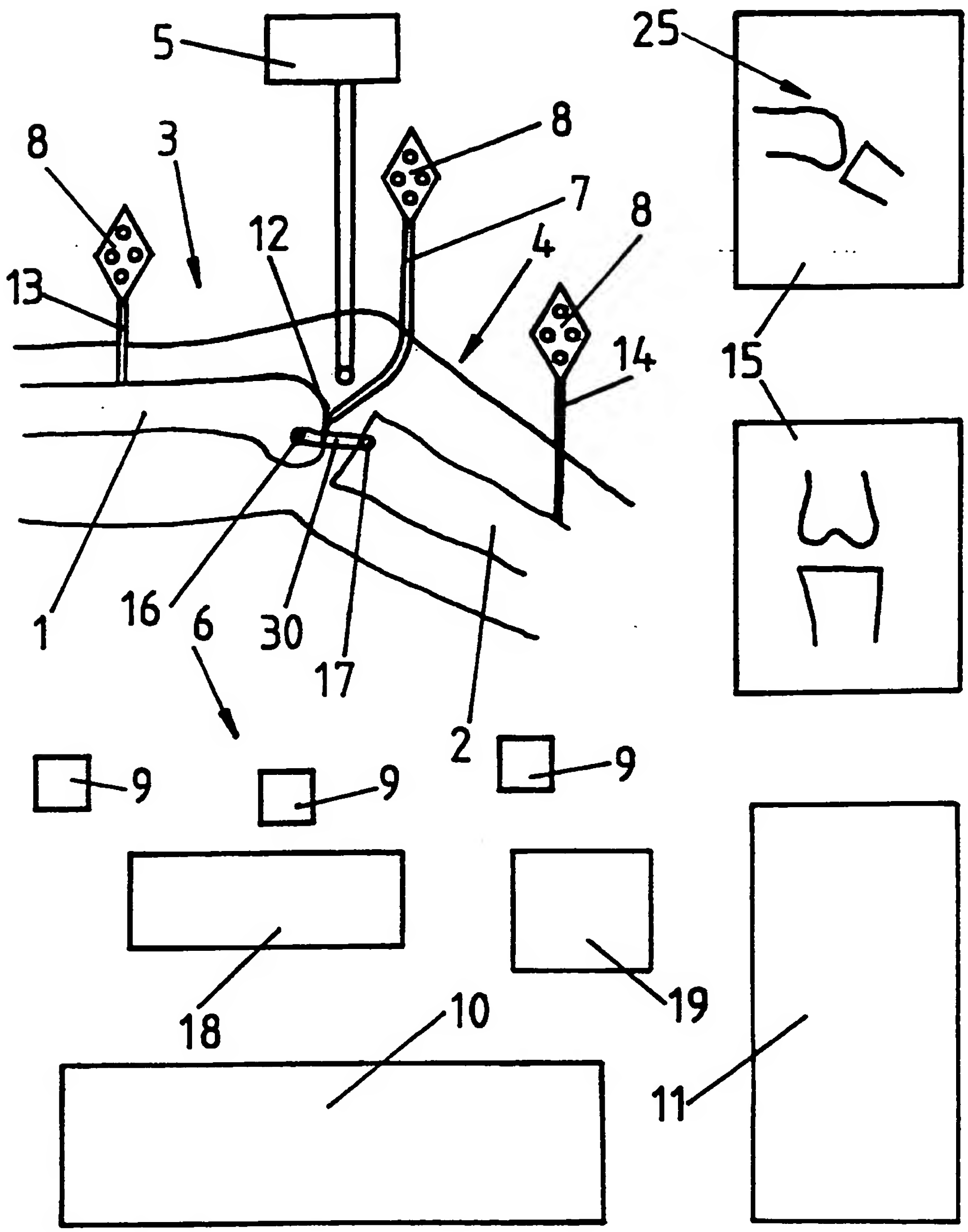

Fig. 1

INTERNATIONAL SEARCH REPORT

Inte onal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B17/17 A61B5/107 A61B5/103

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 603 089 A (UNIV JOSEPH FOURIER) 22 June 1994 see the whole document ---	1-22
X	US 5 682 886 A (DELP SCOTT L ET AL) 4 November 1997 see the whole document -----	1-22

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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